RESOLUTION COPPER MINE

SCREENING LEVEL HUMAN HEALTH RISK ASSESSMENT

Air Sciences Inc. (May 30, 2019)

INTRODUCTION

This screening level assessment of human health risk associated with air emissions from the proposed Resolution Copper Mine (Project) is based on exposure calculations and reasonable and conservative assumptions, as summarized here:

- U.S. EPA's "Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites"[1] are used (in units of µg/m^3 so appropriate to compare with modeled air pollutant concentrations). The RSLs are derived by U.S. EPA using pollutant-specific toxicity values and default exposure assumptions.
- Detailed air emissions dispersion modeling (AERMOD) has been conducted to estimate maximum impacts to air quality at the Project boundary[2]. Maximum annual modeled PM_{10} concentrations are used as the basis for a conservative estimate of long term exposure to inorganic substances contained in wind-blown dust from the Project. In reality, PM_{10} concentrations due to emissions from the Project will decrease with distance from the emissions source so this is a very conservative method that would tend to overestimate exposure.
- Inhalation pathway is assessed.[3]
- Inorganic substances are the constituents contained in dust emissions from the Project and are assessed.[4]

CONCENTRATIONS OF AIRBORNE INORGANIC METALS

Inorganic metals naturally occur in copper ore and, therefore, will be present in tailings produced at the Project and deposited in the Tailings Storage Facility (TSF). Therefore, very small quantities of inorganic metals could be contained in the wind-blown dust from the TSF. Resolution Copper Mining (RCM) has conducted an extensive tailings geochemical characterization program. As part of that program, tailings material samples have been analyzed for concentrations of inorganic metals for which RSLs for carcinogenic and/or non-carcinogenic chronic health effects have been derived by EPA.

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[1] https://www.epa.gov/risk/regional-screening-levels-rsls

[2] Air Sciences Inc., 2018b. Resolution Copper Project NEPA Air Quality Analysis. Prepared for Tonto National Forest. Project No. 262. Golden, Colorado: Air Sciences Inc., November.

[3] Characteristics of the Project and the project area make consideration of the inhalation pathway a reasonable approach and responsive to public scoping comments: arid climate and lack of nearby surface waters reduce the likelihood of metals uptake from surface drinking water; arid climate and lined TSF with seepage controls reduce the likelihood of metals uptake from groundwater drinking water; lack of nearby agricultural activities (e.g., dairy, crops) reduce the likelihood of metals uptake from food consumption.

[4] Source apportionment information in the modeling output shows that almost all (99.4%) of the maximum modeled PM_{10} impact is due to windblown dust from the TSF.

Resolution's tailings management strategy includes separation of tailings into two mineralogically and geochemically discrete streams known as "pyrite" (also known as "cleaner", Potentially Acid Generating (PAG)) and "scavenger" (also known as Non-Potentially Acid Generating (NPAG)) tailings. For all of the TSF alternatives at the Project, except for Alternative #4 – Silver King, PAG tailings will be placed on the TSF and be under water cover and therefore not available to be entrained as windblown dust from the TSF. The screening level risk assessment for all TSF alternatives except Alternative #4 – Silver King is based on inorganic metals content data for NPAG which are shown in Table 1. The screening level risk assessment for Alternative #4 – Silver King (presented in a dedicated section below) is based on inorganic metals content data for NPAG and PAG.

Table 1. Inorganic Metals Concentration in NPAG Tailings Material Samples

Metals	Concentration in NPAG[1]	Units	Percentage of NPAG
Arsenic	1.84	ppm	0.0002%
Barium	304.65	ppm	0.030%
Beryllium	2.18	ppm	0.00022%
Cadmium	0.07	ppm	0.00001%
Cobalt	4.14	ppm	0.0004%
Lead	34.72	ppm	0.003%
Manganese	92.93	ppm	0.009%
Mercury (elemental)	0.05	ppb	0.00000%
Nickel	36.29	ppm	0.0036%
Selenium	0.73	ppm	0.0001%

1. Geochemical Characterization of Resolution Tailings Update: 2014-2016, Duke Hydro|Chem, June 2016; Table 4.4-7; geometric mean of 12 samples.

Maximum annual PM_{10} concentrations due to emissions from the Project are modeled to be 7.27 µg/m^3 at a receptor located on the northwest boundary of the TSF for Alternative 2. Multiplying the maximum modeled annual PM_{10} impact concentration (7.27 µg/m^3) by the inorganic metal percentage of the NPAG tailings in Table 1 results in calculated maximum air concentrations (C_{MAX}) of the inorganic metals, shown in Table 2.

Table 2. Calculated Air Concentrations of Inorganic Metals (NPAG) (PM_{10} = 7.27 µg/m^3)

Metals	Air Concentration (C_{MAX}) (ug/m3)
Arsenic	0.00001
Barium	0.00222
Beryllium	0.00002
Cadmium	0.00000
Cobalt	0.00003
Lead	0.00025
Manganese	0.00068
Mercury (elemental)	0.000000
Nickel	0.00026
Selenium	0.00001

REGIONAL SCREENING LEVELS AND ESTIMATED HUMAN HEALTH RISK

The Screening Levels (SL) are chemical-specific concentrations for individual contaminants in air. The SLs are derived from equations combining exposure assumptions with chemical-specific toxicity values. The exposure assumptions represent Reasonable Maximum Exposure (RME) conditions for long-term/chronic exposures.[5] SLs for carcinogenic risk (SL_C) and/or non-carcinogenic chronic health effects risk (SL_{NC}))have been derived for the inorganic metals listed in Tables 1 and 2. SL_C concentrations represent an excess cancer risk of $1x10^{-6}$ (one in one million). SL_{NC} concentrations represent a Health Index of 1. These human health risk levels are used by U.S. EPA as the basis for the SLs because they are commonly considered acceptable levels of risk.

Assessing health risk for each inorganic metal can therefore be represented by the following equations:

C_{MAX} / SL_C = Cancer Risk Health Quotient (HQ_C)

C_{MAX} / SL_{NC} = Non-carcinogenic chronic health effects Health Quotient (HQ_{NC})

If HQ_C is less than 1, then excess cancer risk is less than $1x10^{-6}$. If HQ_{NC} is less than 1, then the Health Index for non-carcinogenic chronic health effects is less than 1. Table 3 shows the published values of SL_C, SL_{NC} and the calculated HQ_C and HQ_{NC} for each inorganic metal.

[5] Regional Screening Levels (RSLs) – User's Guide, U.S. EPA, 2018. https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#intro

Table 3. Calculated Health Risk Estimates for Inorganic Metals (NPAG)

Metals	Air Concentration (C_{MAX}) (µg/m3)	SL_C (Target Risk = $1x10^{-6}$) (µg/m3)	HQ_C (C_{MAX}/SL_C)	SL_{NC} (Target HI = 1) (ug/m3)	HQ_{NC} (C_{MAX}/SL_{NC})
Arsenic	0.00001	6.50E-04	0.02	1.60E-02	0.001
Barium	0.00222			5.20E-01	0.004
Beryllium	0.00002	1.20E-03	0.01	2.10E-02	0.001
Cadmium	0.00000	1.60E-03	0.00	1.00E-02	0.000
Cobalt	0.00003	3.10E-04	0.10	6.30E-03	0.005
Lead	0.00025			1.50E-01	0.002
Manganese	0.00068			5.00E-02	0.014
Mercury (elemental)	0.000000			3.10E+00	0.000
Nickel	0.00026	5.80E-03	0.05	1.50E-02	0.018
Selenium	0.00001			2.10E+01	0.000
		Sum of HQs	**0.18**		**0.043**

Source of SL_C and SL_{NC}: Regional Screening Level – Resident Ambient Air, U.S. EPA, November 2018.

The sums of the Health Quotient values in Table 3 indicate that the estimated human health risk associated with the maximum air concentrations of inorganic metals are below 1.0 for cancer (less than $1x10^{-6}$ cancer risk) and below 1.0 for non-carcinogenic chronic health effects. This estimate of human health risk is representative for all TSF alternatives except Alternative #4 – Silver King.

ALTERNATIVE #4 – SILVER KING

Human health risk for Alternative #4 – Silver King is estimated by incorporating the inorganic metals concentrations in PAG into the risk estimate calculation. Alternative #4 uses filtered tailings (15% moisture) instead of slurry tailings and the PAG tailings are placed on the TSF without water cover. Therefore, there is the potential for NPAG and PAG tailings to be available to be entrained as windblown dust from the Silver King TSF. Resolution's tailings geochemical characterization program includes inorganic metals analyses for PAG tailings. Metals concentrations in PAG are different from the metals concentrations in NPAG and are shown in Table 4.

Table 4. Inorganic Metals Concentration in PAG Tailings Material Samples

Metals	Concentration in PAG[1]	Units	Percentage of NPAG
Arsenic	23.12	ppm	0.0023%
Barium	16.15	ppm	0.002%
Beryllium	0.89	ppm	0.00009%
Cadmium	0.43	ppm	0.00004%
Cobalt	191.59	ppm	0.0192%
Lead	42.72	ppm	0.004%
Manganese	25.12	ppm	0.003%
Mercury (elemental)	0.06	ppb	0.00000%
Nickel	118.80	ppm	0.0119%
Selenium	59.19	ppm	0.0059%

1. Resolution Copper, Summary_Metals_PAG_Tailings.xlsx; compiled from five studies of PAG tailings; geometric mean of 9 samples.

The planned split of the tailings streams is 85% NPAG and 15% PAG[6]. Therefore, it is assumed that 85% of the surface area of the Silver King TSF will be NPAG tailings and 15% of the surface area will be PAG tailings. The split between windblown dust from NPAG surfaces and PAG surfaces is also assumed to be 85% and 15%, respectively. Air concentrations of inorganic metals estimated due to PAG ($C_{MAX\text{-}PAG}$), NPAG ($C_{MAX\text{-}NPAG}$), and total metals concentration ($C_{MAX\text{-}Total} = C_{MAX\text{-}PAG} + C_{MAX\text{-}NPAG}$) in dust emissions from the Silver King TSF are shown in Table 5

Table 5. Alternative #4 – Silver King Calculated Air Concentrations of Inorganic Metals (PM_{10} = 7.27 $\mu g/m^3$)

Metals	Air Concentration ($C_{MAX\text{-}PAG}$) (ug/m3)	Air Concentration ($C_{MAX\text{-}NPAG}$) (ug/m3)	Air Concentration ($C_{MAX\text{-}Total}$) (ug/m3)
Arsenic	2.52E-05	1.14E-05	3.66E-05
Barium	1.76E-05	1.88E-03	1.90E-03
Beryllium	9.72E-07	1.35E-05	1.45E-05
Cadmium	4.73E-07	4.44E-07	9.16E-07
Cobalt	2.09E-04	2.56E-05	2.35E-04
Lead	4.66E-05	2.15E-04	2.61E-04
Manganese	2.74E-05	5.75E-04	6.02E-04
Mercury (elemental)	6.30E-11	3.09E-10	3.72E-10
Nickel	1.30E-04	2.24E-04	3.54E-04
Selenium	6.46E-05	4.49E-06	6.91E-05

[6] USFS Alternatives Evaluation Report – Draft Final, November 2017

Table 6 shows the published values of SL_C, SL_{NC} and the calculated HQ_C and HQ_{NC} for each inorganic metal in windblown dust as estimated for Alternative #4 – Silver King.

Table 6. Alternative #4 – Silver King Calculated Health Risk Estimates for Inorganic Metals

Metals	Air Concentration ($C_{MAX-Total}$) (µg/m3)	SL_C (Target Risk = $1x10^{-6}$) (µg/m3)	HQ_C (C_{MAX}/SL_C)	SL_{NC} (Target HI = 1) (ug/m3)	HQ_{NC} (C_{MAX}/SL_{NC})
Arsenic	3.66E-05	6.50E-04	0.06	1.60E-02	0.002
Barium	1.90E-03			5.20E-01	0.004
Beryllium	1.45E-05	1.20E-03	0.01	2.10E-02	0.001
Cadmium	9.16E-07	1.60E-03	0.00	1.00E-02	0.000
Cobalt	2.35E-04	3.10E-04	0.76	6.30E-03	0.037
Lead	2.61E-04			1.50E-01	0.002
Manganese	6.02E-04			5.00E-02	0.012
Mercury (elemental)	3.72E-10			3.10E+00	0.000
Nickel	3.54E-04	5.80E-03	0.06	1.50E-02	0.024
Selenium	6.91E-05			2.10E+01	0.000
		Sum of HQs	**0.89**		**0.081**

Source of SL_C and SL_{NC}: Regional Screening Level – Resident Ambient Air, U.S. EPA, November 2018.

The sums of the Health Quotient values in Table 6 indicate that the estimated human health risk associated with the maximum air concentrations of inorganic metals due to windblown dust from Alternative #4 – Silver King are below 1.0 for cancer (less than $1x10^{-6}$ cancer risk) and below 1.0 for non-carcinogenic chronic health effects.

Victoria Boyne

From: ResolutionProjectRecord
Subject: FW: Response to Data Request - Metals Deposition Values
Attachments: Resolution_Screening Levels Based HHRA_May30-2019.docx

From: Peacey, Victoria (RC) <victoria.peacey@riotinto.com>
Sent: Tuesday, June 4, 2019 9:55 AM
To: Rasmussen, Mary C -FS (mary.rasmussen@usda.gov) <mary.rasmussen@usda.gov>
Cc: Ballard, Kami (RC) <Kami.Ballard@riotinto.com>; RCPermitting <RCPermitting@riotinto.com>; Morissette, Mary (RC) <Mary.Morissette@riotinto.com>; Donna Morey <dmorey@swca.com>; Chris Garrett <cgarrett@swca.com>
Subject: Response to Data Request - Metals Deposition Values

Hi Mary,

In response to the data request for metals deposition values associated with air emissions, please see the e-mail below and attached Technical Report from Air Science.

Thanks,
Vicky
From: Dave Randall [mailto:drandall@airsci.com]
Sent: Thursday, May 30, 2019 7:54 PM
To: Ghidotti, Greg (G&I); Ballard, Kami (RC); Peacey, Victoria (RC)
Subject: Re: metal contents in PAG for HRRA

Kami, Greg, and Vickey -

Attached is a WORD file of the revised Health Assessment Document.

If you'd prefer to have this document in an Air Sciences Technical Memo format, let me know and I'll have it converted.

Regards, Dave

Dave Randall, Principal Air Quality Scientist
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